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ABSTRACT

The computer revolution has contributed greatly to the increased use of Geographic Information Systems (GIS) technology, and GIS is now being used to inform education policy. This paper introduces the technology of GIS to education researchers and policy analysts and illustrates its use with some recent research on charter schools. Its potential as an analytic tool in education research is explored. A GIS is a computer-based technology that allows one to create, store, and manipulate geographically referenced information. A GIS can perform queries and statistical analyses on spreadsheet-type data, producing digital maps that contain features in the form of points, lines, or polygons. A GIS was useful in the investigation of whether Arizona charter schools, as schools of choice, had the potential to separate students along racial lines. (Contains 2 figures and 22 endnotes.) (SLD)

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Using Geographic Information Systems in Education Research and Policy Analysis

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ABSTRACT

The computer revolution has greatly contributed to the increased use of Geographic Information Systems (GIS) technology. A technology once limited to a small number of disciplines, GIS is now being used to inform education policy. This paper introduces the technology of GIS to education researchers and policy analysts and illustrates its use with some recent research on charter schools. Its potential as an analytic tool in education research is explored.

Graphic display techniques in GIS's make relationships among map elements visible, heightening one's ability to extract and analyze information.

--U.S. Geological Survey[1]

The computer revolution has greatly contributed to the increased use of Geographic Information Systems (GIS) technology. Powerful and sophisticated GIS software is now readily available and affordable at the desktop-level for social science researchers and geographers alike.[2] A technology once limited to a small number of disciplines, GIS has now found application in disciplines as varied as agriculture, political science, and epidemiology.

In this paper, I introduce the technology of GIS to education researchers and policy analysts and illustrate its use with some recent research on charter schools. Its potential as an analytic tool in education research is explored. We begin with a brief overview of GIS and highlight their conventional applications.

What is a GIS?[3]

A geographic information system is a computer-based technology that allows one to create, store, see, and manipulate geographically referenced information.[4] Unlike CAD (computer-aided design) systems, but much like other database programs, GIS can perform queries and statistical analyses on spreadsheet-type data. The combination of geographical analysis with graphical presentation is powerful.

GIS produce digital maps which contain features in the form of either points, lines, or polygons. Examples of common features include streets, highways, schools, and census tract boundaries. Since the maps are created by and viewed on a computer monitor, it is easy to turn these features "on" and "off."

One of the most powerful and unique aspects of GIS is that map features can be linked to relational databases. Simply by moving the cursor over an area or point of interest and clicking the mouse, a new window appears with information pertinent to the spot of interest. The information can be anything from summary statistics to an image file to a short video clip. This feature of GIS is analogous to the hyperlink technology that pervades our electronic media.[5] In addition, GIS technology offers standard database operations such as query and statistical analysis.[6]

There are a number of GIS software programs on the market including ArcView GIS, Atlas*GIS, MapInfo, and Arc/Info. ArcView is one of the more user-friendly programs, being primarily menu-driven and operating on both Windows and MacIntosh platforms. Arc/Info is more powerful than ArcView, but requires a higher level of computer knowledge and tends to be used primarily by professional geographers. These programs function to create, display, and manipulate digital maps of cities, states, neighborhoods—virtually any data with geographic properties. Further, most GIS software has spatial analysis capabilities.

GIS provide the medium to engage in analytical mapping. First used in the early 1960s, analytic mapping is a blend of cartography and geographic analysis. Analytic mapping is a process that occurs within (or with the use of) a GIS. It permits "geo-statistical" analyses such as areal averaging and centroid computation, thus providing researchers with statistical alternatives to conventional multivariate statistics.[7]

Current Applications of GIS

GIS serve obvious mapping functions, but as an analytical tool their application may be less apparent. GIS are used by environmentalists, agriculturalists, and even social scientists to improve upon existing conditions, solve problems, or contribute to policy and planning efforts. For example, Portsmouth, New Hampshire, used a GIS to help maintain a clean water supply.[8] Agriculturalists have used GIS to expose diseases and improve crop yields. GIS have also assisted in market research, for instance, to determine the best location for a new business. In such applications, census data are commonly used (e.g., identifying average income level and family size within defined geographical regions).

GIS technology is also widely used by city and state planners. For example, in the City of Phoenix the future locations of city parks, libraries, and the like are being decided with the help of a GIS. The City of Tacoma, Washington, created a Crime Analysis Mapping System (CAMS), which allows police to view and track data on burglaries, assaults, and other crimes in conjunction with census data. This information is used to target education efforts, assign patrol units, and study crime patterns.[9] Most state departments of transportation have made the technology a central component of their planning and improvement projects. Emergency services are using GIS to develop and refine emergency routes.

Not unexpectedly, the armed forces has discovered the utility of analytic mapping. During the Gulf War the U.S. was able to produce "near real-time battlefield" maps.[10] More recently, the British Army used GIS to improve soldier recruitment and retention.[11]

Although certainly not widespread, GIS are increasingly being used by schools for a variety of purposes. For instance, many school districts currently use GIS to make busing routes and schedules more efficient.

Social science researchers, education researchers, and education policy analysts are beginning to recognize the unique descriptive and analytical capabilities of GIS. Lee depicted the relationship between geographic location and school-level achievement indicators in the State of Maine.[12] The City of Phoenix, Arizona, was able to demonstrate graphically how schools in more privileged communities have greater access to public libraries, parks, and swimming pools than those in less well-off areas.

GIS & Education Policy Research: An Example

Our research interest concerned Arizona charter schools.[13] More specifically, we wished to address the often mentioned concern that charter schools, as schools of choice, have the potential to separate students along racial lines. Concerns have also been raised that charter schools will tend predominantly to serve white students from racially and ethnically mixed communities.

There are many ways to look for these phenomena. The most common method is to compare the percentage of minority or non-minority students in charter schools with that of traditional (district) public schools. These figures are typically averages and presented at the district, county, or state levels--a practice that does not permit the detection of between-school differences. For instance, a national charter school study reported that in the first year of their operation, Arizona charter schools served 20.2%

Hispanic students while the public schools served 27.6%.[14] The conclusion that charter schools are serving a modestly lower proportion of minority students than regular public schools is appropriate, but appropriate only at the aggregate level. Such data cannot support conclusions about variation at the school level.

A more direct way to detect these phenomena would be to inspect enrollment patterns among neighboring charter and district public schools. If indeed ethnic separation were occurring on the part of charters, we would expect to witness the siphoning of students from nearby (competing) traditional public schools. If, however, there were no ethnic separation occurring, then we would expect to see similar ethnic compositions among propinquitous schools of these two types.

Our research compared the ethnic compositions of Arizona charter schools with those of nearby traditional public schools. For charter schools located in small towns, the comparison was fairly straightforward (e.g., between one charter high school and one traditional public high school). For schools located in the greater Phoenix area, identifying "nearby schools" required the use of geographic maps.

What is meant by "nearby" can be conceived of in several ways, for example, schools that share the same district boundary. In a state like California, where the charter law dictates that charter schools reflect the racial compositions of the district in which they are located, such a strategy seems appropriate. In Arizona, however, most charter schools do not belong to a district.[15] Hence, the most sensible approach is to ignore political boundaries, which is precisely what we did. [16,17] To us, nearby traditional public schools were ones that covered the same student catchment area as the charter school.[18]

The maps conveyed a considerable amount of information—both geographic and otherwise. Canals, major highways, district boundaries, nearest schools of the same grade level, population densities, and the like, all contributed to the cause of identifying neighboring schools.

The ease with which maps are created in ArcView depends almost entirely on the availability of geographic data files. It would be an enormous challenge to digitize a map of say, New York City, if done by scratch. The good news is that many geographic data sets have already been created and can be shared or purchased. Street-level maps of the United States and many other countries are already in digital form. In our research we were able to download a file of metro Phoenix streets at no cost. Even more importantly, this particular file contained street address information which allowed us to geocode (i.e., "plot") schools on our map. We also obtained a census data file from the U.S. Census Bureau's TIGER system (Topologically Integrated Geographic Encoding and Referencing).

In ArcView one works with shapefiles. Shapefiles can be thought of as geographic variables, in a sense, because they represent the layers that comprise a map's features. As mentioned earlier, these layers can be turned on or off, depending on the kind of information one desires to convey. Shapefiles come in three forms: points, lines, and polygons. Our main map consisted of two *point* files (traditional public schools and charter schools), one *line* shapefile (a geographic grid of most every street and highway in metro Phoenix), and three *polygon* shapefiles (district, census tract, and zip code boundaries).

Underlying each shapefile is a table of pertinent data (see Figure 1 as an example). ArcView can display and even manipulate these tables of information. As an

example of the latter, fields can be added to these tables at any time through a simple join command. The table underlying our charter schools shapefile contained several variables such as school name, address, size, percentage of white students, and grade levels served.

In the left hand frame of Figure 1 is a list of shapefiles. You will notice that the public school and Phoenix street shapefiles are checked (or "turned on"), resulting in their appearance on the map. The table entitled *Attributes of Public.shp* contains the data pertinent to the public schools shapefile. It contains various information on each school in metro Phoenix.

Insert Figure 1 about here

Since no shapefile of metro Phoenix public schools had ever been constructed, we had to create one ourselves. ArcView can automate the geocoding process as long as a list of addresses is available. We had a list of school addresses, but many of them were mailing and not physical addresses. ArcView couldn't very well geocode a "P.O. Box," so we were left with the time-consuming process of manually plotting over 100 schools. In the end, we had a digital map of 600 schools that could be viewed in endless ways.

The analysis relied on exploratory techniques within a systematic framework. It was systematic in that we queried every charter school in the metro Phoenix area and summoned maps that displayed their location relative to nearby schools. It was exploratory in the manner in which we identified nearby (or competing) traditional public schools. The dynamic environment of a GIS permits--indeed, encourages--the use of exploratory techniques. In our analysis, there was no "one run of the data." We continued to analyze the data in different ways and continued to draw upon different information before we reached our conclusions. ArcView enabled us to view schools of the same grade level at various scales until we believed the map included traditional public schools that collectively served the same communities as the charter school.

Figure 1 is one of nineteen maps from the original study that provides evidence of ethnic separation. You will notice that in Figure 1 the three elementary charter schools (blue triangles) serve a greater percentage of white students than several of the nearest traditional public schools of similar grade level. The lone exception is the Madison School located in the northwest quadrant of the map; however, one could argue against this school even being considered a "nearby" school given its location relative to the three charter schools. Indeed, this school is located farther away from the cluster of charter schools than any of the other public schools, and further, its position relative to all other schools on the map is separated by a major interstate. No schools and, in fact, no students are located to the immediate north of the charter schools due to a large mountainous region.

It may be worth noting that an elementary district border virtually dissects this map (horizontally). It is not shown here, but if it were, it would fall between Squaw Peak and Indian School roads. Thus a district analysis at the elementary level would preclude the comparison of the three charter schools with those traditional public schools located to their immediate south. This is further reason to ignore artificial boundaries.

Insert Figure 2 about here

In presenting the final maps, we decided to limit the display of school information to type of school, name of school, size of school, and proportion of white students. At the suggestion of John Behrens, contrasting symbols and colors were used to designate type of school (blue triangles for charter schools, red circles for traditional public schools).[19] The contrast makes it easier for the reader to digest the information. There are certainly other ways to present these data (e.g., the Chernoff method), but we found this one to be most visually interpretable.

The maps conveyed the ethnic compositions within a geographic context that was more meaningful than if presented as a table of statistics. We resisted the temptation to assign a number or summary statistic that captured the degree of ethnic separation for each map. Instead, we relied on visualization to illustrate ethnic separation.[20]

Some may be troubled by the absence of a statistical measure of variability (e.g., a segregation index). We felt this would miss the point, confuse the reader, and strip the data of its context. Moreover, it would have corrupted the exploratory nature of the analysis. We concur with Haining, who wrote, "in EDA [exploratory data analysis] it is useful to retain contact with the original data for as long as possible before resorting to techniques that transform or simplify the data."[21] The descriptive maps were an effective medium with which to present the information.

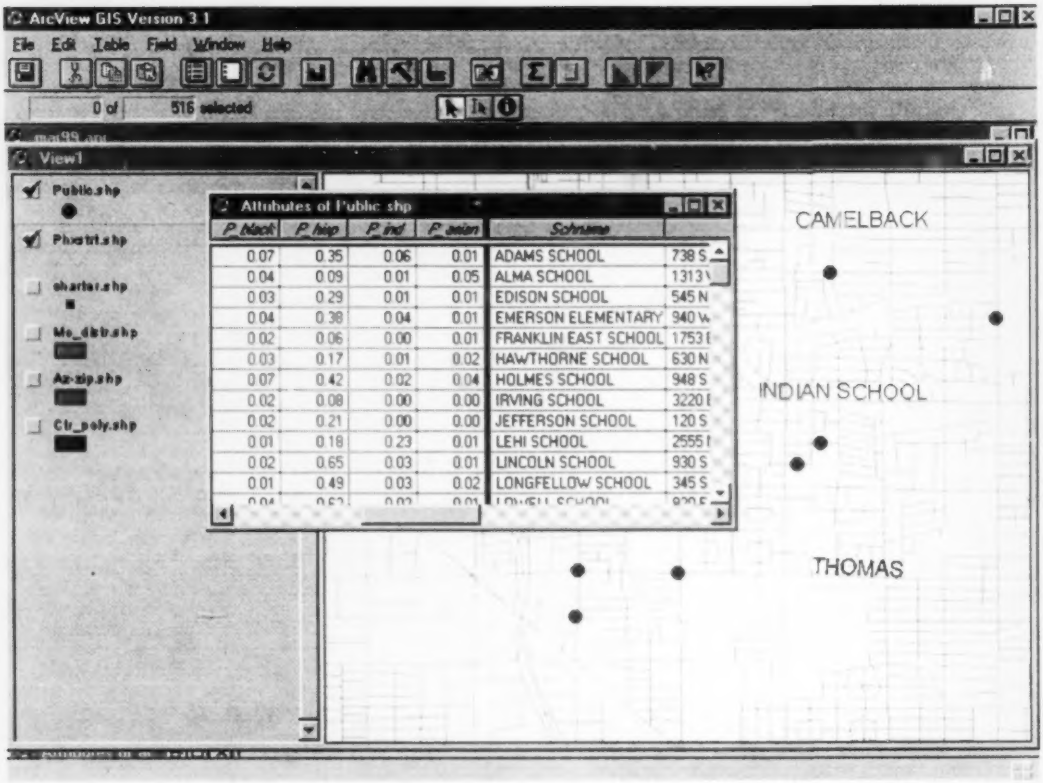
Future Possibilities

The utility of GIS in education research is limited only by our imagination. The example presented above combined exploratory, graphical, and descriptive techniques to detect and present evidence of a phenomenon. GIS can also perform more sophisticated analyses, such as spatial analysis.

Using a similar framework as the one described earlier, one could also inspect for evidence of "creaming" on the part of schools of choice. Creaming, or sometimes called "skimming," is an allegation often directed at schools of choice (whether they be magnet schools, charter schools, or private schools). It refers to the siphoning of academically talented students away from traditional public schools. Thus one might compare schools that draw from common catchment areas on some indicator of academic performance.

Other possible applications come to mind. GIS could assist in the study and prediction of population movements. This could be useful in tracking city-to-suburb shifts in rapidly growing areas such as Las Vegas or Phoenix.

One has to be wary of what I am surely guilty of above in my list of potential studies--that the conventionality or availability of data not bound the research question. GIS research can be more than just about census or population data. I leave it to readers who have a far better imagination than me to conceive of creative ways to use GIS in education research. Considering that it has been estimated that 80% of all local government decisions are made with geography in mind,[22] it seems reasonable for education researchers and policy analysts to begin to study the world in a geographic context.


ArcView GIS Version 3.1
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View1
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0.04 0.09 0.01 0.05 ALMA SCHOOL 1313 V
0.03 0.29 0.01 0.01 EDISON SCHOOL 545 N
0.04 0.38 0.04 0.01 EMERSON ELEMENTARY 940 W
0.02 0.06 0.00 0.01 FRANKLIN EAST SCHOOL 1753 E
0.03 0.17 0.01 0.02 HAWTHORNE SCHOOL 630 N
0.07 0.42 0.02 0.04 HOLMES SCHOOL 948 S
0.02 0.08 0.00 0.00 IRVING SCHOOL 3220 E
0.02 0.21 0.00 0.00 JEFFERSON SCHOOL 120 S
0.01 0.18 0.23 0.01 LEHI SCHOOL 2555 E
0.02 0.65 0.03 0.01 LINCOLN SCHOOL 930 S
0.01 0.49 0.03 0.02 LONGFELLOW SCHOOL 345 S
CAMELBACK
INDIAN SCHOOL
THOMAS

Figure 1. A Snapshot of the Arcview Interface: Relational Table.

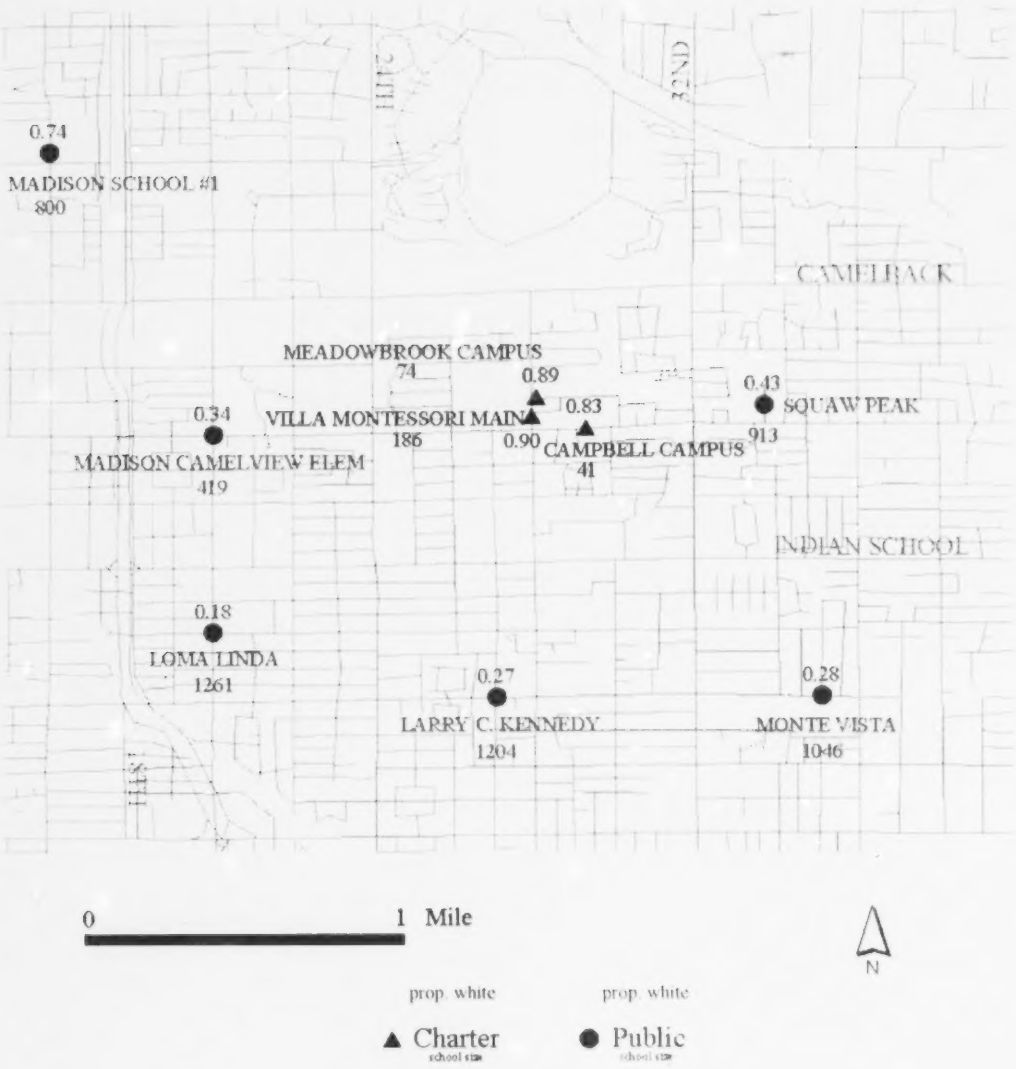

Figure 2. Proportion of white students in
East Phoenix elementary-middle schools in 1996.

Endnotes

[1] USGS (http://www.usgs.gov/research/gis/application6.html).
[2] David G. Garson and Robert S. Biggs, *Analytical mapping and geographic databases* (CA: Sage Publications, Inc., 1992), p. 1.
[3] Although they do share integral features, GIS is sometimes confused with a similar sounding acronym, GPS. GPS is short for "global positioning system," and it uses satellite technology to orient people and things on earth. Orienteering has little to do with what we discuss here, though we are interested maps and map analyses.
[4] United States Geological survey USGS, http://www.usgs.gov/research/gis/title.html.
[5] Ibid. "Through a function known as visualization, a GIS can be used to produce images - not just maps, but drawings, animations, and other cartographic products. These images allow researchers to view their subjects in ways that literally never have been seen before. The images often are equally helpful in conveying the technical concepts of GIS study subjects to non-scientists."
[6] ESRI site, http://www.esri.com/library/gis/abtgis/what_gis.html.
[7] David G. Garson and Robert S. Biggs, *Analytical mapping and geographic databases* (CA: Sage Publications, Inc., 1992), p. 11.
[8] David G. Garson and Robert S. Biggs, *Analytical mapping and geographic databases* (CA: Sage Publications, Inc., 1992), p. 12. Originally in J. Lee and J.M. Douglass, "Utilizing geographic information systems to assist in a municipality's effort to preserve clean water," *URISA*, 1988, vol. 2, pp. 88-96.
[9] Ibid, p. 1.
[10] Ibid, p. 12. Originally in R. Green, "Army rushes upgraded map system to Gulf," *Government Computer News*, February 18, 1991, p. 3.
[11] Christopher Dandeker and Alan Strachan, "Soldier recruitment to the British Army: A spatial and social methodology for analysis and monitoring," *Armed Forces & Society*, vol. 19, 1996, pp. 279-281.
[12] Jaekyung Lee, *Assessing the performance of public education in Maine: Factors influencing school differences*, 1998, Occasional Paper No. 29, Center for Research & Evaluation.
[13] Casey D. Cobb and Gene V Glass, "Ethnic Segregation in Arizona Charter Schools," *Education Policy Analysis Archives*, 1999, vol. 7, no. 1, http://epaa.asu.edu/epaa/v7n1/.
[14] U.S. Department of Education, Office of Educational Research and Improvement, *A study of charter schools: First year report 1997*, 1997, RPP International and the University of Minnesota.
[15] In the fall of 1998, only 9% of Arizona's 214 charter schools were sponsored by districts. Further, district sponsorship does not guarantee the charter is even physically located in that district. Legislation is currently being considered, however, that requires district sponsored charter schools to be located actually within the district's borders.
[16] To a good degree, we used *dasymetric* maps, which are "a type of choropleth map where natural boundaries are used instead of political or other official boundaries." David G. Garson and Robert S. Biggs, *Analytical mapping and geographic databases* (CA: Sage Publications, Inc., 1992), p. 40.
[17] If one were interested in performing a district analysis among Arizona charter schools similar to the California example, there would be no way to do it without the use of maps. Since most charters in Arizona (well over 90%) do not identify with a district, there would be no way of knowing what district they reside in. Arcview has a powerful feature that would enable a researcher to select a district boundary, and then produce a list of schools located within that boundary.
[18] Unlike traditional public schools, charter schools do not have defined attendance zones. We assumed that charter schools served students from nearby communities.
[19] This is another nice feature of ArcView--it has a bank of various symbols and colors to choose from.
[20] We did, however, calculate the percentage of charter schools that demonstrated evidence of the phenomenon to summarily describe the extent of ethnic separation.
[21] Robert Haining, *Spatial data analysis in the social and environmental sciences* (Melbourne, Australia: Cambridge University Press, 1990), p. 225.
[22] David G. Garson and Robert S. Biggs, *Analytical mapping and geographic databases* (CA: Sage Publications, Inc., 1992), p. 2. Originally cited in R.E. Williams, "Selling a geographical information system to government policy makers," *URISA*, 1987, vol. 3, p. 151.